Flex Passive Components

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Searches for relevant components, to see what can be found to fit our constraints:

- Ceramic LV capacitors: local decoupling footprint 0402, global decoupling footprint 0805/1206 (and/or PP1 mount with 1206).
- Note, ceramics preferred to Tantalums for global decoupling. Tantalum have higher capacitance, but also higher ESR, polar construction, susceptibility to current surge failure, etc.
- Ceramic HV capacitor: footprint 1206/0805
- Transient Suppressors: footprint 0603 (or PP1 mount with 0805)
- Temperature Measurement: NTC Thermistor (footprint 0603/0402) vs Pt1000 (footprint 1206)

Ceramic LV Capacitors

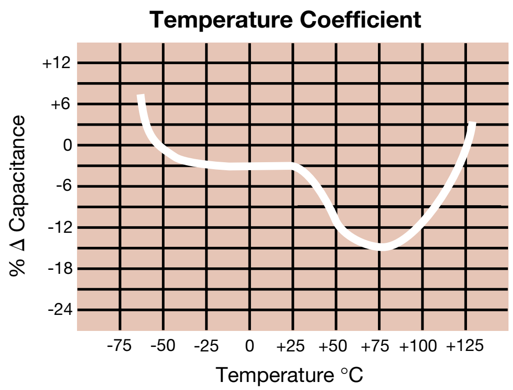
Basic Scheme:

- Local decoupling near each chip (not clear whether this could be every other chip, or must be at each chip). The height constraint of 500μ suggests that 0402 is the appropriate part size, although low profile parts do exist in 0306 footprints. There are now 0201 capacitors, 300μ high, but no large values are presently available.
- Global decoupling at power tape entrance. Here, a part of size 0805 would be preferable, although perhaps a 1206 could be used if it was shown to be essential.

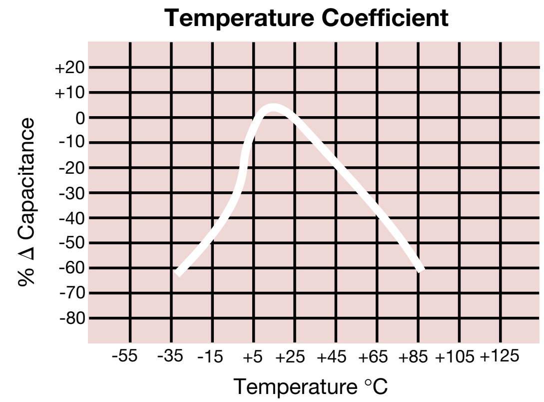
Ceramic dielectrics:

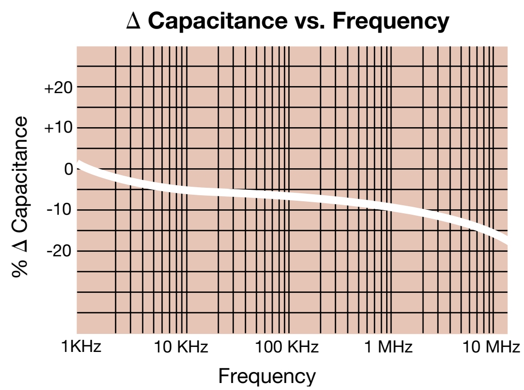
- Three basic classes, with different dielectric constants, all based on $BaTiO_3$. Class I is low capacitiance but very temperature stable (e.g. NPO), and not of interest to us. We are interested in very high capacitance, which implies a ferro-electric dielectric (κ = 5000 - 20000), which in turn will have significant temperature dependence, which can be tuned by introducing impurities in ceramic.
- The high density dielectrics come in two classes, class II (e.g. X7R) has decent T and V coefficients. Class III (e.g. Y5V, Z5U) has very poor T behavior, but gives the best capacitive density.

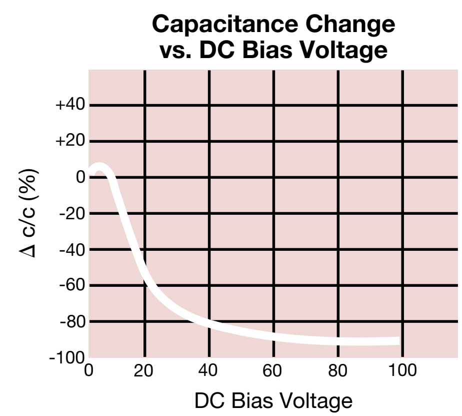
- Over our temperature range, the highest density dielectric (Y5V) has a very significant temperature variation (20 C down to -10 C is more than a factor 2 reduction in C), as well as large aging and voltage coefficients.



- Left is X7R, showing modest T coefficient.
- Right is Y5V, showing large T and V coefficients.







- New dielectric type in use by several vendors called X5R (about twice the value seen for X7R) has an acceptable mean value and temperature variation (10-20%) for our application.
- Claim that 10V rating should be adequate for our needs, but 16V could be better.

Analog capacitors:

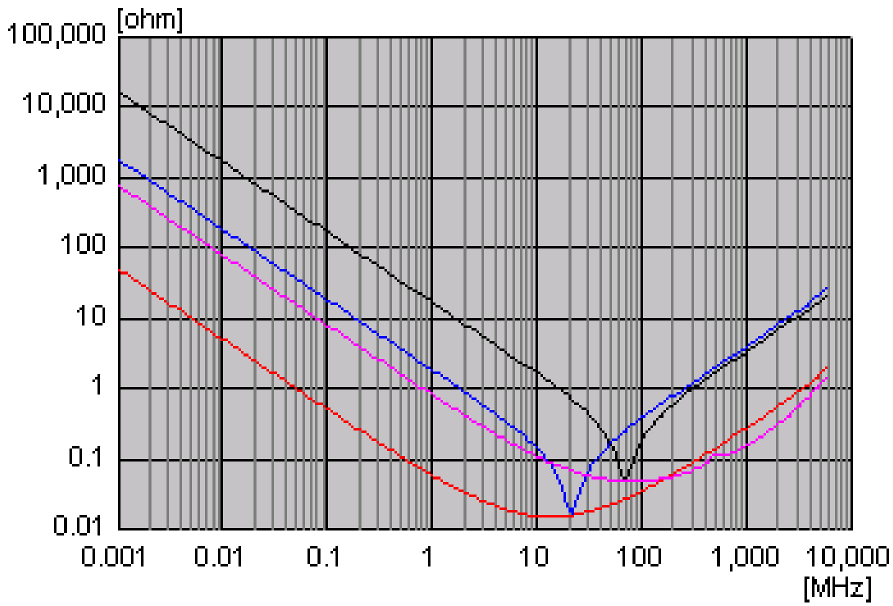
- Capacitors on analog supplies have job of “bypassing” (forcing supply/return to track each other perfectly), so they should have low ESR. Typically, analog circuits have constant power consumption, and the goal is to reduce noise. The sensitive frequency range for the analog supplies is in the few hundred KHz to 10MHz range, with the peak at several MHz. The front-end circuitry is very insensitive to noise at 40MHz and above.

Digital Capacitors:

- Capacitors on digital supplies have job of providing current to circuits whose consumption has rapid and often large variations as switching occurs. The capacitors reduce the large voltage spikes which would otherwise be created by these current variations. In a purely digital system, they are sized to reduce voltage excursions to a level at which the digital circuitry will always work correctly. In mixed-mode systems, they also reduce induced transients on analog supply/return lines. Typically, inductance and high frequency response will be more important.

Selection of Values:

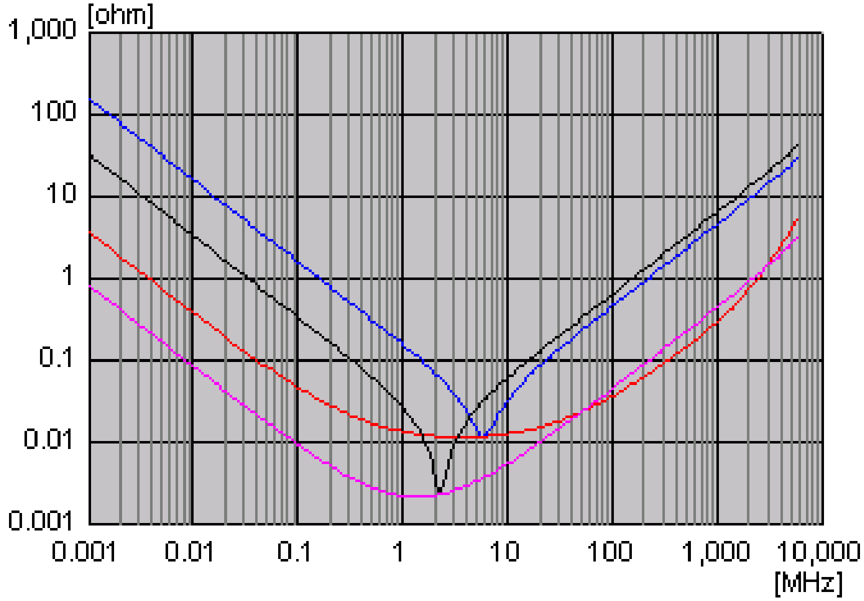
- For local decoupling for analog supplies, would like to get the largest possible value. Values of 0.1µF can now be found at one vendor, and are much more attractive for analog decoupling than conventional values of 0.01µF:



- Black (magenta) curves are impedance (ESR) for 0.01µF part.
- Blue (red) curves are impedance (ESR) for 0.1µF part.

- High value X5R 0402 are presently only available from Murata, with minimum order of 10K parts and some lead time, but they look very attractive for pixels. Values of 0.1µF in Y5V dielectric are available from many vendors.
- Digital coupling may not require such a large value, but it will also provide the best noise reduction in the lower frequency region relevant to the analog supplies.

- For global decoupling, would like to ensure that this decoupling extends to low enough frequencies for ATLAS. Can find the following parts:



- Black (magenta) curves are impedance (ESR) for 4.7μF 1206 part.
- Blue (red) curves are impedance (ESR) for 1.0μF 0805 part.

- In 0805, X5R, largest value available is 1μF with 10V rating. Such parts are available from AVX, Panasonic, and Murata.
- In 1206, X5R, largest value available is 4.7μF with 10V rating. Such parts are available from the same three vendors.
- The larger value is clearly better at bypassing in the region below about 4MHz, which is expected to be quite important for pixels.
- However, these larger capacitors could also be placed at PPB1 instead of on the module itself.

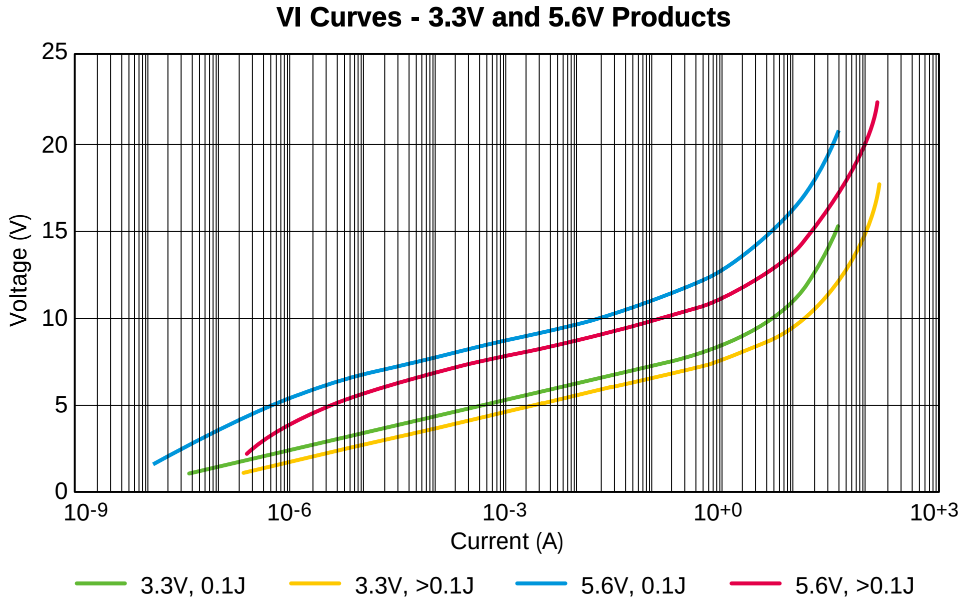
Ceramic HV Capacitors

Role of HV capacitor:

- It is required to complete AC path for small signals from sensor. The current created in the sensor flows into the preamplifier and into analog ground, then through the decoupling capacitor to the p-side Al plate. Want this loop to be as small and as clean as possible for low noise operation.
- Main requirement is for a low ESR in the frequency range of interest for the signal (order of 100 MHz), and so a 1nF value should be enough. This is not mainly a “filter” capacitor, and larger values should not play a useful role.
- Here, we need a 1kV part in order to be comfortable with the 700V maximum operating specification for the sensor bias after irradiation. Many vendors make 1nF 1KV capacitors using X7R dielectrics. In general, none of them make a size smaller than 1206, making this the largest component on the current Flexes. Have used Johanson caps up to now because they offer the largest range of values. Have found one vendor (Novacap) with a 1KV 1nF 0805 capacitor.
- In principle, a significant gap is required between HV and nearest ground, even on a Flex with coverlayer. SCT has chosen to use 2.5mm gap spec for 500V rating (conservative spec without coverlay) in their power tapes. We are using a somewhat more aggressive spec of 3mm for 1KV. However, this would suggest even a 1206 is too small...

Transient Suppression

- Devices of choice seem to be TransGuard product from AVX. These are so-called "varistors", that are ceramic semiconductors based on ZnO. They operate like a pair of back-back Zener diodes, but have a "distributed" junction to provide much better current and energy absorption than Zeners.
- They will switch on in less than 1 ns, but do not have a terribly steep I/V curve. The lowest voltage part is 3.3V. It has a "breakdown" voltage of 4-6V (voltage at which I = 1mA), and an equivalent R less than 1Ω at about 8V:



- Example parts of interest would be 3.3V devices. There is an 0603 part rated at 0.1J and a 0805 part rated at 0.3J. Have sample quantities of 100 of each.

- Clearly, we need to do real prototype tests with dummy loads, prototype power cables, and prototype power supplies. In this case, we can simulate simple transient conditions (large change in current consumption for example), and see how useful such devices would be.
- Below is an example from the vendor literature:

Fig. 6. 12 V Relay Transient without protection
105 V 50 V/Division

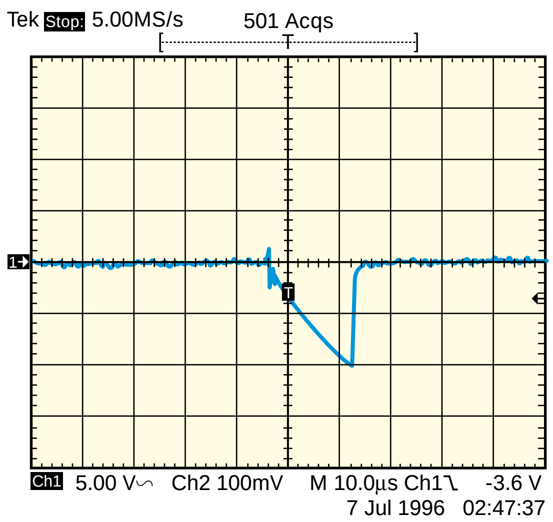
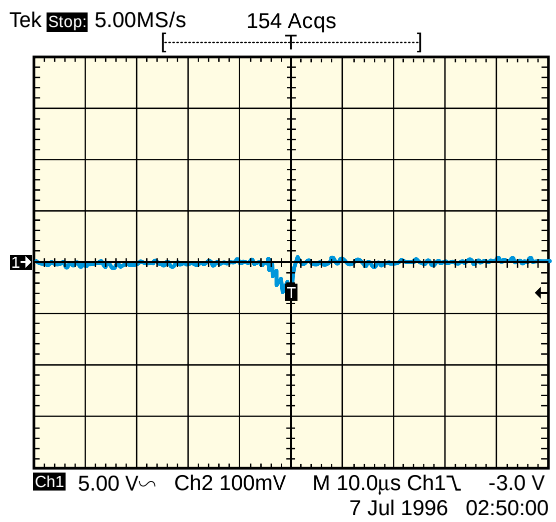


Fig. 6A. 12 V Relay Transient with 14 V TransGuard
30 V 50 V/Division



- These devices could provide vital protection for modules under transient conditions. They typically show little degradation after many hundreds of repeated “strikes”.
- Since they are ceramic devices, would expect them to be rad-hard enough for ATLAS.

Temperature Measurement

- Have used 1206 Pt1000 from IST in Switzerland for recent Flex modules. These parts are about 8 CHF each, but are good to 0.1%. They would typically be read out using a 1mA current source and measuring the voltage.
- There is a useful Analog Devices part to read them out ($5 each) ADT70, designed for readout of Pt1000. It uses matched current sources to provide an accurate output.
- Nevertheless, Pt1000 has typical T coefficient of 0.4% per degree C, so a high quality measurement is needed.
- Instead, ceramic NTC thermistors have a coefficient of about 4% per degree C, and are more compact and cheaper than Pt1000. An example is the Murata 1% part, 10KΩ, available in 0402 or 0603 sizes (NTH5G16P33B103F).
- Its resistance is 10+/-0.1 kΩ at 25 C, and extrapolates to 42.5KΩ +/-1.0KΩ at -10 C, corresponding to an overall error of about +/-0.5 C at this temperature. Recent work by Wuppertal has shown that similar parts are very radhard, and maintain their specifications after full pixel radiation doses.
- Such devices only require a 100μA current source for their operation, so there are no self-heating effects. Would suggest we put about 4 of them in the corners of the module to measure the average module temperature by putting them in series. They can be nicely digitized by AD7711 ($15) 24-bit RTD ADC.